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THE EFFECT OF LIGHT ABSORPTION RATE ON GRAIN SIZE DETERMINATION BY LIGHT SCATTERING METHOD

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THE EFFECT OF LIGHT ABSORPTION RATE ON GRAIN SIZE DETERMINATION BY LIGHT SCATTERING METHOD

[Hikari sanranho ni yoru ryukei sokutei ni okeru hikari kyushuritsu no eikyo]

by

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In light scattering methods of measuring particles, in which photocounters or photometers are used to measure the light scattering phenomena in the particles, and the sizes or the concentrations of the particles are discovered, the measurement characteristics are affected to a considerable degree by the optical characteristics of the particles, that is, by their refractive index. The influence is said to be remarkably great especially in cases when the values are complex numbers, that is, in cases when the light absorption rate of the particles must be

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taken into consideration. The effects of this light absorption rate of the particles on the light scattering measuring characteristics of particles were considered by means of clarifying theoretically the complex number refractive index dependency of the light scattering characteristics of the particles, which forms the basis for this influence. The results are reported herein.

When the particles are spherical, isotropic, and homogeneous, according to Mie's scattering theory, when a natural light with an intensity I_0 and a wavelength λ is scattered by particles with a diameter Dp at a refractive index m, the scattered light intensity I at a scattering angle θ measured at a distance r from the particle center from the direction of movement of the incident light will be given by the following:

$$I = \frac{I_0 \lambda^2}{8\pi^2 r^2} (i_1 + i_2) \tag{1}$$

Here, i_1 and i_2 are the vertically and horizontally polarized component scattered light intensity distribution functions. As functions of the particle size parameter α ($= \pi D_p/\lambda$), the scattering angle θ, and the particle refractive index m, they are given by the following:

$$i_1 = \left| \sum_{n=1}^{\infty} \frac{2n+1}{n(n+1)} (a_n \pi_n + b_n \tau_n) \right|^2 , \quad i_2 = \left| \sum_{n=1}^{\infty} \frac{2n+1}{n(n+1)} (a_n \tau_n + b_n \pi_n) \right|^2 \tag{2}$$

$$a_n = \frac{S_n(\alpha) S_n'(m\alpha) - m S_n'(\alpha) S_n(m\alpha)}{\Xi_n(\alpha) S_n'(m\alpha) - m \Xi_n'(\alpha) S_n(m\alpha)} , \quad b_n = \frac{m S_n(\alpha) S_n'(m\alpha) - S_n'(\alpha) S_n(m\alpha)}{m \Xi_n(\alpha) S_n'(m\alpha) - \Xi_n'(\alpha) S_n(m\alpha)}$$

$$\pi_n = P_n'(\cos\theta) , \quad \tau_n = \cos\theta \, P_n'(\cos\theta) - (1 - \cos^2\theta) P_n''(\cos\theta) , \quad \Xi_n(\alpha) = S_n(\alpha) + i C_n(\alpha)$$

Sn and Cn are Riccati-Bessel functions of the n-th degree, and Pn is a Legendre's polynomial of the n-th degree.

The particle refractive index m, in connection with the dielectric constant ε, the conductivity σ, and the circular frequency of light ω ($= 2\pi C/\lambda$), may be written as $m = (\varepsilon - i4\pi\sigma/\omega)^{\frac{1}{2}}$ when the magnetic permeability is 1. Thus, if we write $m = n_1 - in_2$, the following relationships will occur: $n_1^2 + n_2^2 = \varepsilon$, $2n_1n_2 = 4\pi\sigma/\omega$. The value of n_2 will be greater in metallic particles with a greater σ.

Since the actual particles generally have a broad range of their refractive indexes n_1 and n_2, and since ε and σ also have a great dependency upon ω, n_1 and n_2 also have a great dependency on λ. Here let us first examine directly the degree of the influence of n_2, the imaginary number portion of the refractive index, on the scattering factors i_1 and i_2 $(i_1 + i_2)$. The relationships between i_1, i_2, and $(i_1 + i_2)$ and n_2 for cases where $m = 1.50 - in_2$ at $\alpha = 10$ and $\theta = 10$, 60, and 90° are shown in Figs. 1, 2, and 3. An extremely characteristic finding which can be stated from these figures is the fact that the rate of reduction of the scattered light intensity is remarkably great at the smaller values of n_2, while the rate of reduction becomes smaller when n_2 increases. Next, in order to investigate the influence of the real number portion of the refractive index, n_1, on this tendency, the relationship between $(i_1 + i_2)$ and n_1 in cases where $m = n_1 - in_2$ at $\theta = 60°$ and $\alpha = 3$, 10, and 50 is shown in Figs. 4, 5, and 6 for $n_2 = 0$, 0.05, 0.1, 0.5, and 1.0. The influence of n_1 is great in cases where the value of n_2 is small, but the influence declines as n_2 increases. It is clear that at $n_2 = 1.0$, $(i_1 + i_2)$, together with the angular scattering angle, is almost independent of n_1.

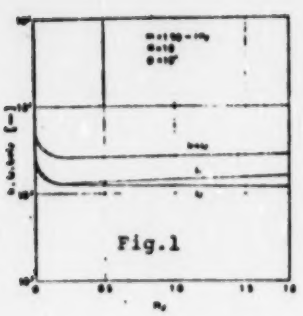

Fig.1

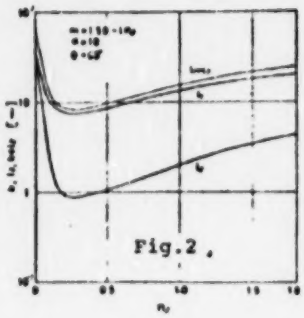

Fig.2

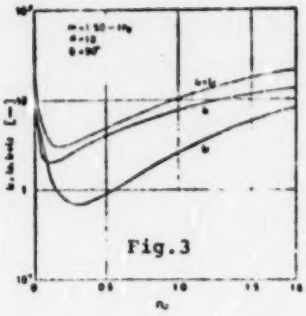

Fig.3

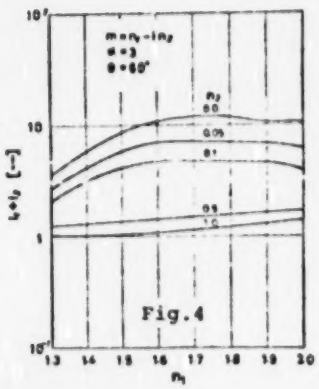

Fig.4

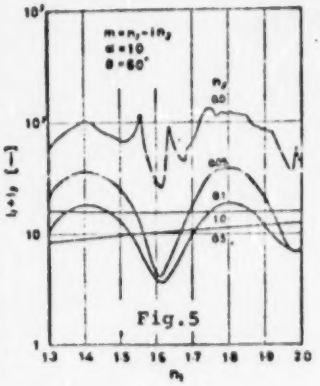

Fig.5

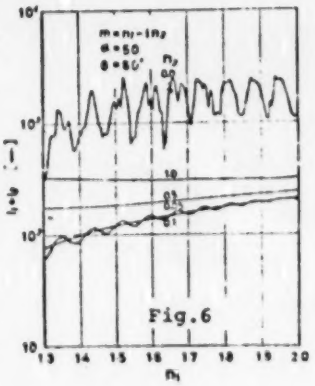

Fig.6

Furthermore, in order to study the influence of n_2 on the scattering angle distribution pattern of $(i_1 + i_2)$, the relationship between $(i_1 + i_2)$ and θ at $n_1 = 1.5$ and $\alpha = 3$, 10 was plotted with reference to n_2 in Figs. 7 and 8. The fluctuations of the scattered light intensity with respect to θ became smaller the greater was n_2. This influence is pronounced with larger values of α, where the fluctuations are intense in degree. Generally speaking, although there are some differences depending upon the scattering angle, the influence of n_2 decreases the

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smaller is α.

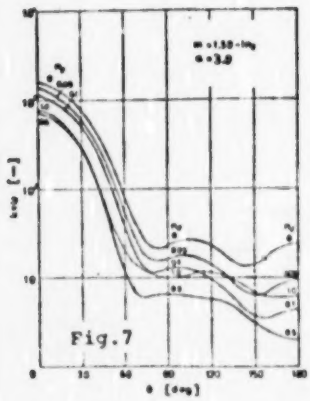

Fig.7

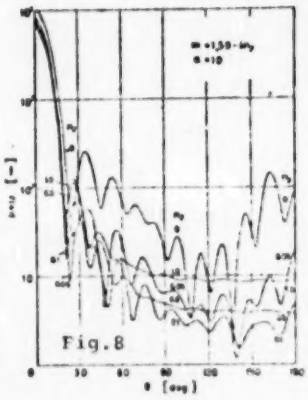

Fig.8